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# ~~X~~ WATER YIELD FROM SNOW AS AFFECTED BY CONSUMPTIVE WATER LOSSES<sup>1/</sup>~~X~~

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The snow which accumulates each winter on high elevation forest and rangelands has long been known to be the principal source of the water supply for most of the West. The conservation of that snow resource has become of major concern as demands for more water have grown apace with the needs of an expanding economy.

There are several possibilities of meeting the future water needs of the West. One is to build more storage dams and transmountain diversions. We can also tap more of the ground water basins. There is room too for reducing the waste of already developed water supplies by improving our water conveyance systems and by using water more efficiently. In addition there is the possibility of reducing the consumptive losses of snow water by altering the vegetation on the watershed lands where runoff begins.

The idea of reducing evapo-transpiration losses of snow water by watershed management practices is both intriguing and hydrologically sound. There is evidence, however, that the benefits which may accrue from changing the plant cover may be offset by a number of adverse effects. The purpose of this paper is to point out some of those conflicting possibilities in the hope of clarifying the thinking about watershed management problems, especially those within the Intermountain region.

## Plant Cover Influences

The role that vegetation plays in the disposition of snow has been well established by research. The part played by plants, as described by Kittredge (4) and more recently by Colman (2), actually embraces many specific influences. These can probably be most readily understood by considering their effects during the several processes that are usually involved in the transition of snow to runoff.

The most obvious influence of plant cover is its capacity to intercept snow, thereby causing some of the snow water to be evaporated into the air before it reaches the ground. This effect usually varies directly with the density and height of the plant cover. Snow interception

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losses, for example, tend to range from less than .5 inch on areas of low growing vegetation to as much as 5.0 inches on areas having a dense and mature stand of coniferous trees.

Plant cover exerts a second influence after snow accumulates on the ground. Dense forest cover tends to reduce wind velocities near the snow pack surface and also shades the snow. These effects lessen direct evaporation from the snow, a loss which may amount to as much as 2.0 inches per month on untimbered slopes. It is not uncommon also for reduced evaporation and melting rates under a forest canopy to compensate for interception losses with the net result that the lesser accumulation of snow there may take longer to melt than a greater accumulation of snow on open areas.

Vegetation exerts a third group of effects when water melts from the snow mantle and becomes available for storage in the soil or for runoff. One of these effects is the action of stems in keeping melted snow water spread out and moving slowly over the land surface. The litter and humus keeps the surface soil absorbent. Plant roots and other biological activity deepen and loosen the soil, thereby increasing its capacity to transmit water to cracks and fissures in the underlying rock mantle.

These plant cover effects, together with the relatively low temperatures and slow snowmelt rates that usually prevail on the more elevated watershed lands in the Intermountain region, all favor the infiltration of melted snow water into the soil mantle and the slow delivery of part of that water to streams and ground water basins. This process is sometimes referred to as seepage flow runoff. Runoff rarely occurs as overland flow on the high elevation watershed lands primarily because snowmelt rates are generally less than the infiltration and percolation capacity of the soil mantle, even when the plant cover is depleted.

Poor watershed management can upset the normally slow delivery of seepage water to stream channels. Overgrazing and improper skidding of logs, for example, commonly lead to the development of gullies in normally smooth soil surfaces. Any such cuts in the soil surface provide for the rapid escape of free water moving laterally in the soil. Even though there may be no overland flow on the ungullied areas, the quickened movement of water into a newly established drainage system can raise peak flow discharges during snowmelt and may lessen the recession stages of flow later in the year.

A fourth important plant cover effect takes place after melted snow water is stored in the soil mantle. It is known that many mountain soils can hold about 3.0 inches of water per foot of soil depth against the force of gravity. It is also known that about 1.0 inch of the stored water is held so tightly by the soil particles as to be unavailable to plants, whereas the other 2.0 inches can be extracted from the soil by evaporation and transpiration.

The transpiration of plants is relatively unimportant on sites where the soil is less than about 2.0 feet deep because all of the



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so-called available water can be lost to the atmosphere solely by evaporation during the summer season. On areas with deeper soils, plant cover and more particularly the depth and extensiveness of root systems, become very important. On such areas, each additional foot of depth to which plants extract water below the 2.0-foot depth level means the creation of an additional 2.0 inches of retention water storage capacity that will have to be recharged by the next snowmelt before seepage flow runoff can occur. In short, the amount of melted snow water that becomes available for seepage flow runoff varies inversely with the depth of the plant root system and the completeness with which the soil mantle is dried out by the end of the preceding growing season.

### Net Hydrologic Effects

The combined effect of these several influences of plant cover on the hydrologic behavior of the land has been tested on both entire watersheds and plots. Though these tests have been limited to but a few of the numerous watershed conditions that exist in the West, they have furnished some valuable clues to the role that watershed management can play in the conservation of the snow water resource.

There is ample evidence that removal of vegetation or substantially thinning it tends to increase the amount of runoff from the land. It is also evident that the amount of increased runoff will diminish in time as vegetation rebuilds to its normal density and height.

One of the classic examples of the effect of removing vegetation on water yields is the behavior of the watersheds in the Wagon Wheel Gap experiment that was conducted in Colorado several years ago (1). In that study the timber was cut on one watershed and the area was then burned. A similar, adjacent watershed was not treated. Cutting and burning increased the water yield about 25 percent during the first year or two but by the seventh year there was little difference in the water yield between the treated and untreated areas. The resumption of normal water yields was attributable mainly to the sprouting and growth of aspen.

A plot experiment at the Fraser Experimental Forest in Colorado showed that the creation of openings in a dense lodgepole pine forest so reduced consumptive water losses--mainly by snow interception--as to make up to 30 percent more water available for streamflow on the cutover spots (6). Inasmuch as the heaviest cutting treatment removed the trees on about half the forest area, the immediate over-all effect was about a 15-percent increase in the amount of water available for streamflow. How long this local effect will persist has not been determined, but presumably will diminish as regrowth fills in the cutover spots.

Based on an entirely different principle, Croft determined the amount of water that would be made available for runoff by removing all of the aspen trees from a series of plots on the Davis County Experimental Watershed in Utah (3). He found that the deep-rooted aspen on



untreated plots removed 4.0 inches more water from the soil mantle than was extracted by a more shallow-rooted cover of herbaceous plants after the aspen trees were cut out. Completely bared areas lost 4.0 inches less water than those with herbaceous cover. The latter condition was considered entirely unsatisfactory because of the large amounts of soil erosion and stormflow runoff that occurred during the summer rain season. The study, however, clearly demonstrated the effects of different root depths on the recharge requirements of the soil mantle.

The annual or seasonal amount of water yield is but one of three important characteristics of runoff. The other two are the rates at which water is discharged and the quality of water, especially the amount of sediment carried by streams.

It has been well established that any increase in amounts of runoff above normal limits during snowmelt are almost certain to step up peak flow discharges and to also cause increased channel erosion. Both increased peaks and erosion occurred in the cut and burned Wagon Wheel Gap watershed previously referred to. Both have also been commonly observed to follow denudation by fire elsewhere. There are indications of similar results following extensive forest denudation by insect epidemics.

The effects of plant cover depletion on runoff rates and sediment production are even more pronounced on areas that are subject to torrential summer rains in addition to the melting of winter accumulations of snow. On the Davis County Experimental Watersheds in northern Utah, for example, neither plant cover depletion nor restoration of plant cover on depleted areas--exclusive of changes in streambank vegetation caused by channel erosion--have had any appreciable effect on snowmelt runoff. Depletion of the range cover on as little as 10 percent of the watershed lands, however, has brought about a drastic change in the control of summer storm runoff. In one such depleted watershed, the melting of some 40 inches of snow water produced a maximum discharge of about 20 cubic feet per second per square mile whereas a high intensity summer rain of less than 1.0 inch in volume caused a mud-rock flood on the order of about 2,000 c.s.m. (5).

Restoration of normal plant cover conditions on depleted lands has long been recognized as an effective means of minimizing flood runoff and of stabilizing eroding soil. Low-growing herbaceous plant cover as well as forest trees, can be highly effective in controlling summer storm runoff and erosion. The 36-year-long record of one of the experimental, high elevation summer range watersheds at the Great Basin Research Center in central Utah shows that even partial revegetation--involving an increase in herbaceous plant cover density from 16 to 50 percent--has reduced sediment production from about 2.00 acre feet per square mile of watershed area per year to about .06 acre foot per square mile per year (7). Preventing the unleashing of the tremendous sediment production potentials that exist on the steep watershed lands of the Intermountain region and the control of erosion where it has



already been accelerated obviously are important aspects of watershed management which must be considered along with the possibilities of increasing the amount of runoff from those lands.

### Productivity Effects

The yield of water is but one of two important functions of forest and rangelands. The other is the production of useful supplies of wood, forage, and wildlife. The productive function of the wild lands is especially important in the Intermountain region when it is considered that limited water supplies preclude the intensive occupancy and cultivation of more than about 5 percent of the land area. Keeping the other 95 percent of the lands in a productive condition is highly essential to the economy of the region.

The accomplishment of the production part of the wild land management job while at the same time maintaining conditions that are favorable to the maximum yields of useful runoff is not a simple assignment. On the one hand, we now know that some minimum amount of plant cover must be kept on the watershed slopes to maintain soil stability and minimize the occurrence of destructive floods. On the other hand, vigorous plant growth is essential to maximum timber and forage production. To meet these two requirements of good wild-land management and at the same time bring about a reduction in the consumptive losses of snow water, leaves only one solution. That is to find the kind and amount of plant cover which will make the most efficient use of the precipitation that falls on the watersheds.

An exploratory study of the amount of water consumed and the amount of forage produced during one growing season by four kinds of summer range cover was recently completed at the Great Basin Research Center in central Utah. The four kinds of cover included pure stands of smooth brome, timothy, Kentucky bluegrass, and a mixture of dandelion and sweetsage. The latter mixture is commonly found on depleted, high elevation, herbaceous rangeland. The difference between the field moisture capacity of the soil following the spring snowmelt and the depleted moisture content in the fall plus the amount of summer rainfall provided a basis for estimating the seasonal evapotranspiration losses. The difference between the late fall soil moisture content and field capacity also provided a basis for determining differences in water recharge requirements and amounts of water that would be available for streamflow from the next year's snow pack. Estimates of forage production were obtained by clipping and weighing current plant growth.

Smooth brome plots consumed the most water but also produced the most forage and made the most efficient use of the water consumed. The 350 pounds of forage produced per inch of water consumed is about as good as can be obtained on irrigated valley lands. By comparison, areas with timothy consumed 0.79 inch less water and produced less than half as much forage. Kentucky bluegrass areas consumed about



1.00 inch less water than those with timothy but were more efficient in the use of water. The weed areas consumed the least water but were also by far the least efficient in forage production (Table 1).

Table 1.--Summer season evapo-transpiration losses, differences in water available for streamflow and forage production under four plant cover conditions on high elevation summer range, Utah

Range cover	Evapo-transpiration loss (Inches)	Water available for streamflow (Inches)	Forage production	
			Total (lbs./A.)	Unit (lbs./A./in.)
Smooth brome-grass	11.33	0.00	3,220	350
Timothy	10.54	0.79	1,440	135
Kentucky bluegrass	9.47	1.89	1,980	210
Dandelion-sweetsage	8.96	2.37	715	80

The variability in the water consuming efficiency of these four types of summer range cover suggests the possibility of achieving different objectives on range watershed lands.

Where maximum forage production is desired, management should strive to establish a plant cover comparable to that produced by smooth brome-grass. That grass develops not only a shallow rhizomatous root system, but also extensive fibrous roots which occupy the soil to depths of 5 or 6 feet. Under these conditions it could be expected that virtually all of the available soil moisture may be extracted from the soil by the end of the growing season, thereby requiring a maximum amount of melted snow water to recharge the mantle next year.

Where water yields are more important than forage, a close growing type of plant cover with less deep rooting habits, as is typical of Kentucky bluegrass, appears to be the most desirable. Under such conditions, less water from melting snow will be required to recharge the soil mantle and more of the winter precipitation will therefore be available for streamflow.

Thin stands of taprooted forbs appear to have no place in watershed management, particularly on steeply sloping mountain lands that are subject to torrential rains. Though that kind of plant cover may consume a little less water, the amount it does consume is an exorbitant price to pay for low volume and poor quality forage, for unstable soil, for damaging sedimentation, and potentially violent floods.

In the foregoing, only a few examples were given of some of the hydrologic and productivity consequences that can follow an alteration of the natural plant cover on high elevation watershed lands of the



West. They were chosen for the two-fold purpose of demonstrating that it is entirely feasible to decrease the consumptive losses of snow water but that extensive efforts to achieve that end should not be undertaken unless the several other and possibly conflicting results are fully understood. It is to be hoped that the present meager amount of tested information about the several possible effects of watershed management can be enlarged by more research.

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